Are Northern Hemisphere Tropospheric Ozone Densities Larger?

Volker W. J. H. Kirchhoff
Instituto de Pesquisas Espaciais INPE,
São Paulo, Brazil

Tropospheric ozone densities at two tropical stations are compared. Contradicting previous evidence, the southern hemisphere measurements show ozone densities larger than those collected at the northern hemisphere station.

It has been claimed that northern hemisphere (N.H.) tropospheric ozone densities in the tropics are higher than those measured at southern hemisphere (S.H.) stations [*Fishman et al.*, 1979, and references therein]. It is implied that such a result would be normally expected due to higher concentrations of hydrocarbons in the N.H., especially methane and carbon monoxide, therefore favoring the production of ozone [*Chameides and Walker*, 1975] through the so-called methane oxidation reaction chain (or its equivalent, starting from CO). Attractive as this idea is, we must point to a priori contradicting evidence, which shows larger ozone densities in the S.H.

We have analyzed two independent data sets, one from Ft. Sherman, Panama (9°N), and the other from Natal, Brazil (6°S). Both data sets have been gathered using balloon-borne ECC ozonesondes. Several other aspects of the Natal data have been discussed by *Kirchhoff* et al. [1981] and *Kirchhoff et al.* [1983].

The number of measurements and their distributions in time are shown in Figure 1. The Natal data have been gathered mostly around noon UT, over a period of about 3 years (1979–1981), following a schedule of about two launchings per month to provide ground truth for overhead satellite passages, whereas the Ft. Sherman data have been collected in a fast sequence during a special NASA campaign during the month of July 1977. The Panama station is located within the Intertropical Convergence Zone, whereas Natal is not.

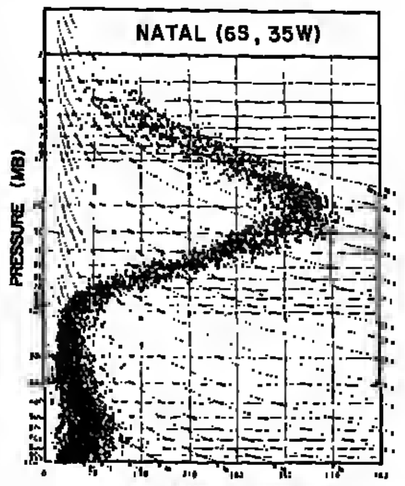

Fig. 2. Mass plot of ozone data taken at Natal. Abscissas are expresed in gammas (μg/m³).

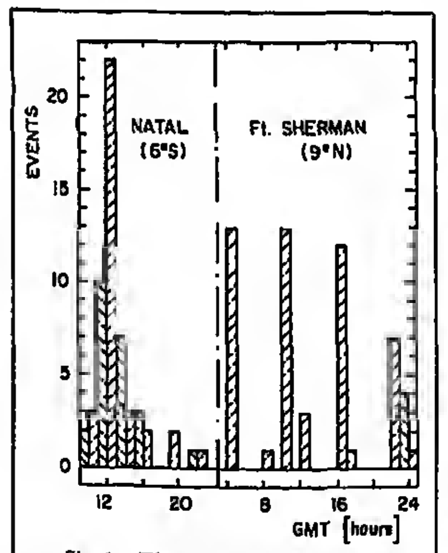

Fig. 1. Time distribution of ozone soundings at Natal and Ft. Sherman.

Figure 2 shows a mass plot of the Natal ozone data as a function of atmospheric pressure. The abscissa gives ozone densities expressed in gammas (μg/m³). A tendency for the formation of a secondary ozone peak in the lower troposphere can be clearly seen at 600–700 mbar. In terms of tropospheric aeronomy, this can be explained through a tropospheric ozone source, if the eddy diffusion coefficient is constant in the troposphere. More discussion on this point is given after Figure 4, which shows the average ozone density profile based on this set of data.

Fishman et al. [1979] have concluded that there is a real hemispheric difference in the densitites of tropospheric ozone in the tropics, in which larger values would be found in the N.H. This conclusion was reached in part on the basis of the data then available (43 soundings from Panama, 31 from Canton Island (2°S), and 10 from La Paz (16°S)), reproduced in Figure 3 by the continuous lines. The abscissas show mixing ratios by volume as a function of height. Our results for Natal and Ft. Sherman (shown by triangles and circles, respectively) clearly contradict the earlier results. It should be noted that the continuous line data were obtained using different types of ozonesondes, whereas for the data that we present the same types of sondes and the same data reduction techniques were used, which probably can justify a lesser degree of confidence in the earlier data.

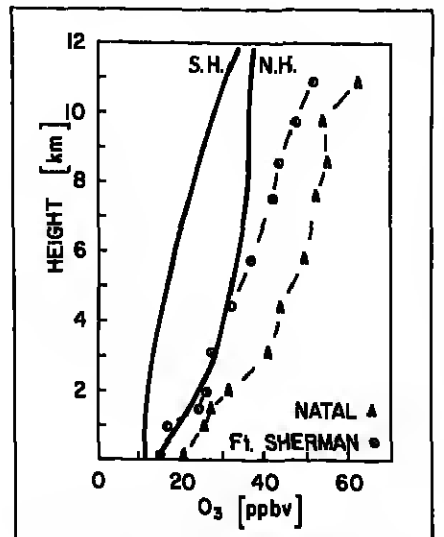

Fig. 3. Comparison of ozone mixing ratios used for northern and southern hemisphere comparisons and the data analyzed in this work for Natal and Ft. Sherman.

In Figure 4 we show the tropospheric ozone density profiles in terms of ozone concentrations as a function of height. The size of a typical standard deviation is shown by the horizontal bar. Again it is clear that the S.H. station (Natal) shows more ozone than the Panama station. But the point we want to stress in this figure is the presence of a peak of the ozone density in the lower troposphere. If it is assumed, as is usual, that the eddy diffusion coefficient K is constant in the troposphere it is easy to see that these profiles cannot be reproduced by the usual constant flux models. Applying the diffusion equation [*Hunten*, 1975],

$$\psi = -K(dn/dz + n/H)$$

(where n is the ozone density, H is the density scale height, and ψ is the ozone flux) at a point above and below the density maximum it is clear that below the peak the downward flux of ozone must be larger than at any point above it. In other words, a local source of ozone at about the height of the peak must exist for the extra supply of ozone. Thus, the basic argument of *Fishman et al.* [1979], that there is an in situ photochemical source of ozone in the troposphere is not challenged, although in this case the S.H. ozone densities in the troposphere are larger than those of the N.H. station.

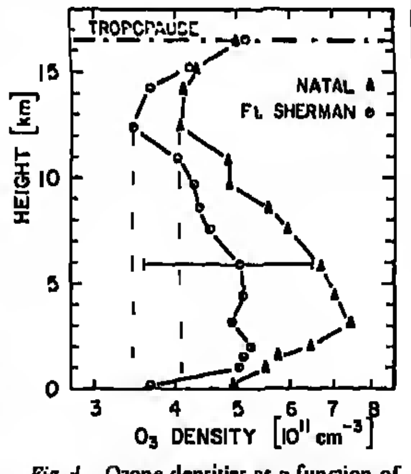

Fig. 4. Ozone densities as a function of height for Natal and Ft. Sherman with evidence of a peak in the lower troposphere.

Other explanations for a secondary ozone peak in the troposphere are presently under investigation. Among these, meteorological processes may be important and possibly also a strong variation with height of the eddy diffusion coefficient.

No definitive answer can be given presently for our title question, but the data gathered so far at Natal show larger tropospheric ozone densities than those measured in Panama, which contradicts previous results. This occurs despite lower densities of CH_4 and CO expected in the S.H. and is related, perhaps, to differences in the nitrogen oxide densities. On the other hand, the secondary tropospheric ozone peak in the data may imply the presence of a tropospheric ozone source. There is an obvious need for additional measurements.

Acknowledgments

I am grateful to I. J. Kantor, Y. Sahai, and B. Clemesha for useful discussions. A. Motta and J. Alves are responsible for the Natal operations, and at the Natal range thanks are due to commanding officer Colonel Sidney Azambuja and his Air Force personnel. The Natal data have been collected under a program of cooperation between INPE, the Brazilian Institute for Space Research, and NASA. I thank E. Hilsenrath, A. Holland, A. Torres, R. Barnes, and A. Grothouse for their interest and support. This work was partly supported by the Fundo Nacional de Desenvolvimento Científico e Technológico under contract FINEP-537/CT.

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Volker W. J. H. Kirchhoff *obtained his Ph.D. in 1975 at The Pennsylvania State University. Employed by the Brazilian Institute for Space Research (INPE) since 1970, his basic interests have been atmospheric research in the ionosphere and mesosphere, as well as teaching in INPE's graduate student programs in space science. Most of his publications have been on the atmospheric sodium layer. In 1978 he helped to start a long-term ozone measurement program at Natal in cooperation with NASA and ever since has been deeply involved in this research area.*

News

The NASA STE Project

The NASA Upper Atmosphere Research Program has funded a multi-year, multi-mission project, the Stratosphere-Troposphere Exchange (STE) Project, whose goal is to improve our understanding of the processes by which trace constituents are exchanged between the stratosphere and troposphere. The project is managed by the Atmospheric Experiments Branch, NASA Ames Research Center. Project scientist is E. F. Danielsen, and project manager is P. B. Russell, both of Ames Research Center. Scientific guidance is provided by an executive committee chaired by J. R. Holton, University of Washington. Project plans call for five major missions using the NASA U-2 and ER-2 high altitude aircraft in the extratropics, the subtropics, and the equatorial region in the years 1984–1987.

Although stratosphere-troposphere exchange has been studied for a number of years, the relative roles of bulk advective overturning (the so-called Brewer-Dobson cell) and eddy mixing on scales ranging from planetary waves to convective clouds and small-scale turbulence remain controversial. The objectives of the project include identifying and quantifying both upward and downward tracer transfer processes with special emphasis on the mechanisms for water vapor transport into the stratosphere.

The project field missions will rely on newly developed instrumentation for the U-2 and ER-2 research aircraft. The aircraft will be equipped with a meteorological measurement system including an inertial platform and air motion sensors. Fast responding in situ sensors will measure ozone, total odd nitrogen, carbon monoxide, water vapor, and total water (vapor plus evaporated ice crystals), condensation nuclei, small and large aerosols, and the two-dimensional image of ice crystals. Potential vorticity will be computed from the wind shears (flying perpendicular to the flow) and the stability measured by a vertically scanning microwave radiometer. Also, for anvil cloud studies two infrared radiometers (one broad band with 2π viewing angle, operating in a vertical flipping mode, and the other a narrow band, narrow solid angle operating in a downward-looking mode) will provide measurements to assess radiative cooling rates above and in the upper portion of the anvil.

Flights in the extratropical stratosphere planned for spring 1984, autumn 1985, and spring 1986 will study exchange associated with upper tropospheric jetstreams. Flights will be directed normal to the axis of a jet stream and/or across multiple jets to measure and correlate the mixing ratios of trace gases and aerosols with one another and with the quasi-conservative potential vorticity. Air of stratospheric origin will be identified by positive correlations between potential vorticity, ozone, total odd nitrogen, and aerosols containing radioactive beryllium 7 and phosphorous 32. Conversely, negative correlations are expected between the above tracers and carbon monoxide, water vapor, condensation nuclei, and radon. Initial flights will determine spatial variabilities; subsequent flights in the extratropics and tropics (see below) will be designed to measure fluxes and to study the transfer processes.

Cloud oriented flights in the tropical stratosphere are planned for January 1987, following a practice mission in the summer of 1986 above a large cumulonimbus anvil, probably over the mountains of Colorado. These flights will be oriented particularly toward attempting to understand the dynamics of water vapor transport into the stratosphere to solve the puzzle of the extreme aridity of the stratosphere. Previous experiments conducted with the NASA Ames Research Center U-2 in the Panama Canal Zone have shown that the Brewer "freeze dry" mechanism for dehydrating the stratosphere is not adequate to explain the very low observed mixing ratios near 19 km in Panama. A dehydration mechanism proposed by Danielsen (*Geophys. Res. Lett.*, *9*, 605–608, 1982) will be tested by flying over and descending into the upper portion of a dense cirrus anvil which is assumed to form in the lower atmosphere. The dehydration mechanism depends upon strong radiative cooling at the anvil's top, plus radiative heating at its base to maintain a turbulent upward vapor flux, rapid ice crystal growth in supersaturated vapor near the top, and a downward flux of ice crystals from the anvil base. In addition, flights will be designed to test the dehydration potentials of slow ascending motions identifiable by the presence of a thin ice crystal cloud.

The major experiment of the STE project series is proposed to be conducted in the Micronesian area using a base in northern Australia. This region and time of year have been selected because they include the coldest and highest monthly mean tropopause temperatures. These conditions, which are associated with intense cumulonimbus convection and massive cirrus anvils, are thought to be ideal for dehydration of air entering the stratosphere.

Plans are still being formulated for ancillary measurements to support the ER-2 flights during the Micronesian experiment. Enhanced satellite coverage, surface-based re-

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News *(cont. from p. 449)*

mote sensing, and balloon-based measurements would all be useful. Scientists interested in possible participation should contact the project manager, Philip B. Russell, Chief, Atmospheric Experiments Branch, 245-5, NASA Ames Research Center, Moffett Field, CA 94035.

This news item was contributed by James R. Holton, University of Washington, and Edwin F. Danielsen and Philip B. Russell, NASA Ames Research Center.

Upcoming Hearings in Congress

The following hearings and markups have been tentatively scheduled for the coming weeks by the Senate and House of Representatives. Dates and times should be verified with the committee or subcommittee holding the hearing or markup; all offices on Capitol Hill may be reached by telephoning 202-224-3121. *For guidelines on contacting a member* of Congress, see *AGU's Guide to Legislative Information and Contacts* (*Eos*, April 17, 1984, p. 159).

July 26: Tentative schedule of markup of Uniform Science and Technology Research and Development Utilization Act (H.R. 5003) by the Science, Research, and Technology Subcommittee of the House Science and Technology Committee. Rayburn Building, Room 2318, time to be announced.

July 26 and July 31: Conference on the Export Administration Act reauthorization (S. 979). July 26, Rayburn Building, Room 2172, 2:30 P.M.; July 31, the Capitol, Room S-207, 3:00 P.M.

July 26: Hearing on UNESCO by the International Operations Subcommittee of the House Foreign Affairs Committee. Time and room to be announced.

TBA: Conference on legislation to consolidate and authorize certain atmospheric and satellite programs and functions of the National Oceanic and Atmospheric Administration. Date, time, and room to be announced.—*BTR*

Marginal Ice Zone

A multidisciplinary team of scientists, including meteorologists, oceanographers, physicists, and biologists from more than 10 countries, are in the process of wrapping up a study of ice packs and their relationship to the environment of the East Greenland Sea. The study, known as the Marginal Ice Zone Experiment (MIZEX '84), continues and expands on last February's MIZEX '83 pilot program that mapped ice movement and studied ice pack behavior in the Bering Sea (*Eos*, October 4, 1983, p. 578, and December 21, 1982, p. 1220).

Seven ships and eight aircraft are participating in the MIZEX experiment, which is designed to report during the months of June and July on the dynamic interaction of the ice with the ocean and atmosphere. "There has not been, at one time, such a complete multidisciplinary project," according to Ken Davidson of the U.S. Naval Postgraduate School, who is chairman of the experiment's meteorological component.

Each season the edge of the polar ice field in the Arctic Sea moves northward or southward as much as 600 km. These shifts in position and energy balance in turn affect weather patterns for the entire northern hemisphere. The MIZEX experiment uses in situ measurements by ships moored to the ice pack as well as remote sensing from aircraft to obtain a thorough study of the dynamic interactions. One ship is moored to the ice 30–50 km inside the edge of the ice field, while the others are arrayed around that central point within a "box" approximately 200 km square. As the location of the box shifts around with the movements of the ice pack, the ships monitor conditions of the upper ocean, the atmospheric boundary layer, and ice characteristics, where appropriate. An array of transponders relays data on ice deformation while reconnaissance aircraft are mapping the entire moving box with synthetic aperture radar, microwave cameras, and sensors.

"We want to study the melting and movement of the ice—the evolution and changing of the ice edge," says Davidson. "The atmosphere and ocean control these changes, and the processes are simply not well understood."

Waterman Award

Nominations are now being accepted for the Alan T. Waterman Award, which annually recognizes an outstanding young scientist in the forefront of science. The award, named for the first director of the National Science Foundation (NSF), was established by Congress in 1975 to mark the agency's silver anniversary.

Candidates for the 1985 award must be U.S. citizens and must be 35 years old or younger (or not be more than 5 years beyond receipt of the Ph.D. degree by December 31, 1984). Candidates should have completed sufficient scientific or engineering research to have demonstrated through personal accomplishments outstanding capability and exceptional promise for significant future achievement, the award committee says. In addition, those nominated should exhibit quality, innovation, and potential for discovery in their research.

In addition to a medal and other recognition, the recipient will receive a grant of up to $50,000 per year for up to 3 years for scientific research or advanced study in the physical, biological, mathematical, medical, engineering, social, or other sciences at the institution of the recipient's choice.

Six copies of each nomination should be submitted to the Alan T. Waterman Award Committee, National Science Foundation, Washington, DC 20550. Additional information and nomination forms may be obtained from Lois J. Hamaty, executive secretary for the award committee (telephone: 202-357-7512). The award is announced every May. For candidates to be considered for the 1985 award, nominations must be received by December 31, 1984.

Acid Rain Report Focuses on Forests

Recent research on acid precipitation yields "increasing general concern about possible effects on forests," according to the second annual report of the National Acid Precipitation Assessment Program (NAPAP). Prepared by the Interagency Task Force on Acid Precipitation, the report outlines the accomplishments of the national program during fiscal 1983, summarizes the current state of scientific knowledge (including a change in the baseline acidity of precipitation), and describes the outlook for current progress by federally funded acid precipitation research. Chris Bernabo is the program's executive director.

NAPAP's annual report agrees with the finding of a National Research Council (NRC) committee that a linear relationship exists between sulfur dioxide emissions and wet deposition of sulfate (*Eos*, July 26, 1983, p. 475). NRC's Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation, which issued its report last year, was chaired by Jack G. Calvert of the National Center for Atmospheric Research.

While not blaming acid deposition for the "environmental stress" on North American and European forests, the report states that "evidence analyzed during the past 3 years indicates that significant changes in growth and vitality of some species have occurred in the eastern U.S. forests." The report adds, "It appears that forests in the United States may be responding to stresses that have been occurring for the past 2–3 decades."

The report also notes that the baseline acidity of precipitation needs to be changed from a pH of 5.6 to 5.0. "Early estimates of the natural pH of precipitation were based solely on the equilibrium of carbon dioxide in the atmosphere with 'pure' water," the report explains. "A pH of 5.6 was subsequently chosen as the baseline against which the seriousness of current acid precipitation levels was judged. It is now clear that other natural factors, such as organic acids, naturally emitted sulfur and nitrogen compounds, and alkaline dust, also affect precipitation's normal acidity. Any baseline pH must account for these factors and the 5.6 value is no longer appropriate." Using the pH 5.6 baseline, scientists had concluded that the eastern United States received precipitation 25 times more acidic than expected in natural precipitation. Using the new baseline of 5.0, however, regions in the United States with the most acidic annual average precipitation are "estimated to receive 6–7 times the average background natural acidity of remote areas."

The national program is divided into 10 task groups: natural sources, man-made sources, atmospheric processes, deposition monitoring, aquatic effects, terrestrial effects, effects on materials and cultural resources, control technologies (funded under other preexisting programs), assessments, and international activities. Progress of research during fiscal 1983 and a research outlook are detailed for each.

The program's overall task force is chaired jointly by the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA). Other participating federal agencies are the Department of the Interior, the Department of Health and Human Services, the Department of Commerce, the Department of Energy, the Department of State, the National Aeronautics and Space Administration, the Council on Environmental Quality, the National Science Foundation, and the Tennessee Valley Authority. The task force also includes four presidential appointees and the directors of the Department of Energy's Argonne, Brookhaven, Oak Ridge, and Pacific Northwest national laboratories.

Copies of the National Acid Precipitation Assessment Program's 1983 annual report to the president and Congress may be obtained by writing to the NAPAP Executive Director, c/o EOP Publications (Room 2200), 726 Jackson Place, N.W., Washington, DC 20503.

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Ocean Engineering Research/University of California, San Diego. The Institute of Marine Resources at the Scripps Institution of Oceanography, University of California, San Diego has three openings for assistant/associate research engineers or assistant/associate professors to participate in the development of ocean engineering programs. Candidates should have a Ph.D. or equivalent in engineering, physics or oceanography, a publication record and should have interest in taking part in research in one or more of the following fields: 1) deep ocean waves, remote and in situ measurement and analyses of directional spectra, and wave/structure interactions, 2) floating and fixed platforms, response to waves, structural analysis, corrosion and fatigue, 3) ocean floor geotechnical studies, initiation of mass movements, scour and soft bottom anchors. The salary range is $25,100-$35,300, depending upon qualifications. Appointment duration two years with possibility of indefinite extension. Appointment as professor is subject to the availability of an appropriate department billet. Appointment at the associate level requires a record of successful funded research. Associate professor rank requires teaching experience. Send resume and names of references before 1 September, 1984 to: F. N. Spiess, Director, Institute of Marine Resources, or R. J. Seymour, Head Ocean Engineering Research Group, Institute of Marine Resources, at Scripps Institution of Oceanography, La Jolla, CA 92093.

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The University of Adelaide, South Australia. Invites applications from both men and women for the following positions:

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APPLICATIONS, IN DUPLICATE, quoting reference numbers and giving full personal particulars (including residential status), details of academic qualifications and names and addresses of three referees should reach the Senior Assistant Registrar (Personnel) at the University of Adelaide, GPO Box 498, Adelaide, South Australia, 5001, Telex UNIVAD AA 89141 not later than 30 September 1984.

The University reserves the right not to make an appointment or to appoint by invitation.

Applied Organic Chemist/Geochemist. A leader is sought for a six-person group involved with federally funded research on the sampling, characterization, and fate of anthropogenic organic chemicals in the environment. The successful applicant will have had a minimum of seven years post-Ph.D. research experience, at least three years of which will have been as principal investigator/project manager, including such activities as selecting, directing, developing, motivating and evaluating professional staff members, and interacting with potential or existing sponsor representatives. Demonstrated capability to initiate and conduct original, high-quality research is essential. Strong written and oral English language skills and the ability to communicate effectively with individuals in other disciplines are required. A strong record of technical publications and successful program development is essential. Applicants with interest in groundwater systems or atmospheric contaminants will be given special consideration, but those with other interests in environmental organic chemistry/geochemistry should not hesitate to submit their credentials.

The individual selected for this position will be responsible for a state-of-the-art organic analytical laboratory located in a major Midwestern research facility, with access to a wide range of supporting chemical-analytical and computer facilities in the parent organization.

Detailed professional histories should be sent to: Box 027, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

An affirmative action/equal opportunity employer.

Rensselaer Polytechnic Institute, School of Science/Dean. Rensselaer is a private, coeducational, non-denominational technological university formed of Schools of Architecture, Engineering, Humanities and Social Sciences, Management and Science. The School of Science contains Departments of Biology, Chemistry, Geology, Mathematical Sciences/Computer Science and Physics and offers B.S., M.S. and Ph.D. degrees in these fields as well as in interdisciplinary areas.

The Institute has mounted a major program of growth of the School of Science. In common with the Institute as a whole, the School of Science looks forward to continued expansion of graduate and research activity. Dean of Science candidates are expected to have a strong background in one or more of the relevant sciences and to have demonstrated a commitment to excellence in both education and research. Pertinent administrative experience is a strong positive factor. Paramount are the qualities of vision, judgment and leadership to match the opportunity offered by the projected growth of the School of Science.

The position will be open in early 1985. Deadline for applications is August 30, 1984. Please send nominations and applications to:

Professor Charles P. Bean, Chairman
Dean of Science Search Committee
Science Center
Rensselaer Polytechnic Institute
Troy, NY 12180

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Faculty Positions In Geophysical Sciences/The University of Chicago. The Department of the Geophysical Sciences invites applications for positions at all levels across the entire range of earth and planetary sciences, including meteorology and oceanography. Particular attention will be given to applications in interdisciplinary areas with prospects of major advances in observation, theory and application. Please send resume and reprints to Joseph V. Smith, Chairman, Appointments Committee, 5734 South Ellis Avenue, Chicago, Illinois 60637, USA. Applications will be considered rapidly throughout the year.

The University of Chicago is an equal opportunity/affirmative action employer.

Bedford and Royal Colleges/Lecturership In Geology. Applications are invited for a new lectureship in the department being created by the amalgamation of the geology departments of Bedford, Chelsea and King's Colleges. The field of specialization and level of appointment is open but a very strong interest and/or considerable experience of radiogenic isotope geology is essential. Gross salary range (under review) £8,376—£15,311 p.a. Further particulars and application form (returnable by 14 September) may be obtained by sending s.a.e. to Personnel Secretary, Bedford College, Regent's Park, London NW1 4NS, England.

Postdoctoral Fellowship/Geophysical Institute, University of Alaska, Fairbanks. Ph.D. in Physics with extensive course work in all areas of Physics. Preference will be given to candidates with some experience in one or more of the following: 1) experimental work in infra-red spectroscopy, 2) digital electronics, and 3) numerical modeling. Work will involve field observations of airglow and auroral emission analysis and some teaching. Salary at least $34,800/year D.O.E. One year appointment with renewal of up to two more years. Write to: Dr. Abas Sivjee, Geophysical Institute, C.T. Elvey Building, University of Alaska, Fairbanks, AK 99701. Deadline for applications: 8-31-84.

University of Alaska is an equal opportunity/affirmative action employer. Your application for employment with the University of Alaska may be subject to public disclosure if you are selected as a finalist.

Scripps Institution of Oceanography, Geological Research Division: Postdoctoral Research Stable Isotopes/Sedimentology. Applications are invited for a postdoctoral position in the Geological Research Division of SIO. We are looking for candidates with a strong background in chemistry, and an interest in paleoceanography, paleoclimatology, or carbonate geochemistry and sedimentology. Preference will be given to persons experienced in the operation and maintenance of mass spectrometers. Level of appointment and salary will be commensurate with experience, according to University of California standards. Applications and curriculum vitae (2 copies), and references, should be addressed to Drs. W.H. Berger or M. Kastner, Scripps Institution of Oceanography, La Jolla, CA 92093, A-015, before August 15, 1984.

Geophysicist. Challenging position in Seoul, Korea requires degree in geophysics and three years related work experience or ten years experience in geophysics methods with four years interpreting field data from instrumentation. Modern computer competency required. Excellent salary, cost of living differential, and comprehensive benefits. For interview call Ron Baptie at 703-960-8505 or send resume to: VSE Corporation, 2550 Huntington Avenue, Alexandria, VA 22303.

An EOE M/F/V/H.

POSITIONS WANTED

Exploration Geologist. Specializing in resource exploration and development (mineral, petroleum, and groundwater—also mining and petroleum engineering). Johns Hopkins PhD with extensive practical experience in the Middle East and elsewhere. Multilingual (fluent in Persian and Turkish). Reply to Box 025, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

Thermosphere Dynamics II. October 3–5, 1984 Goddard Workshop on Thermosphere Dynamics II. Ramada Inn, Calverton, MD. Chairman, Hans G. Mayr, Goddard Space Flight Center (Alcia E. Johnson, Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD 20771).

This meeting will assess our current understanding of thermosphere dynamics and identify new directions for scientific research in this specialty. Data recently obtained from the Dynamics Explorer spacecraft system and new measurements from ground-based facilities allow us to quantitatively address questions regarding thermosphere-ionosphere-magnetosphere coupling processes. The emphasis of the workshop will be on describing the structure (temperature, composition) and dynamics of the neutral thermosphere. Some topics that will be discussed are: Thermospheric Energization Processes, Long Term Variations and Superrotation, Gravity Waves, Mesosphere-Thermosphere Coupling, and Planetary Thermospheres. Titles for contributed papers should be submitted by July 31, 1984.

NATO Advanced Study Institute/Large Scale Transport Processes In Oceans and Atmosphere. Les Houches, French Alps, February 11–22, 1985.

A primary objective of the course is to develop understanding of the large scale atmospheric dynamics, ocean dynamics and the interactions between ocean and atmosphere. The principal lecturers (Blackman, Gill, Hoskins, Rhines, Welander) will cover the above topics, starting at a relatively simple level and developing them to advanced research level. In addition, a number of more specialized lectures will be given by supporting lecturers.

The Institute is intended for graduate students or young postdoctoral researchers. Limited funding is available. Students should write to Dr. J. Willebrand, Institut für Meereskunde, Dusternbrooker Weg 20, D-2300 Kiel 1, W. Germany, for further information, as soon as possible.

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

For speediest treatment of contributions send three copies of the double-spaced manuscript to one of the editors named below and one copy to AGU.

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Washington, DC 20009

Cover. This shear zone in quartz diorite represents an early stage in the formation of fault gouge. The sample originated 518 m below the surface in Stone Canyon, San Benito County, California, and was collected while drilling a well 1.2 km from the creeping segment of the central San Andreas fault in 1972. Alteration has softened plagioclase grains, while quartz grains appear brittle. Preliminary analysis suggests that the dark bands separating the shear zone from the relatively undeformed rock are comprised of chlorite and mixed-layer illite-montmorillonite. The shear zone is about 30 mm wide at the center of the figure. (Photo submitted by Don Stierman and Al Williams, Institute of Geophysics and Planetary Physics, The University of California, Riverside, Calif.)

An Invitation

Would you like to be on the cover of *Eos*? If you have any illustrations with both aesthetic charm and scientific interest—photographs (preferably black and white) of geophysical phenomena, experimental results, or graphs—*Eos* would like to consider them for publication on the cover. Send the original illustration or 8 x 10 inch (20 x 25 cm) glossy photo with a short (50–200 words) explanation that can serve as a caption. You may also submit a more extensive news item or even a short article to accompany a proposed cover. Captions will be by-lined. If the material has been previously published, please supply a copyright release from the copyright owner. Send it to *Eos* Cover, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

AGU

1984 James B. Macelwane Awards

Mary K. Hudson

Citation

Mary Hudson is being honored as one of the 1984 James B. Macelwane award winners because her theoretical research on the microphysics of magnetospheric plasmas has been at the forefront of the field, has inspired many experimental and theoretical studies, and has stimulated her colleagues and students.

From her earliest work as a graduate student, Mary has displayed a pronounced talent for recognizing a challenging problem, understanding the experimental data, formulating a theoretical approach, theoretically interpreting the data, and working with experimentalists on the consequences of her theory. Her Ph.D. research, on the equatorial Rayleigh-Taylor instability, called Equatorial Spread *F*, was undertaken on her own initiative and produced a sophisticated collisional, linear instability analysis which showed that drift waves play an important role in this phenomenon. Her collaborations with experimentalists verified this result and led to an analytic nonlinear solution for the evolution of two-dimensional plasma bubbles that are now known to occur in Equatorial Spread *F*.

After completing her Ph.D. thesis at the University of California, Los Angeles, in 1974, Mary joined the research staff at the Space Sciences Laboratory of the University of California, where data from the S3–3 satellite were being analyzed to characterize the auroral particle acceleration region. In this region, which exists at an altitude of about 6000 km above the auroral ionosphere, electrons are accelerated by plasma processes to kilovolt energies, after which they impinge on the upper atmosphere to produce the brilliant luminosity that we know as the aurora. In spite of intensive research on the physics of the aurora and of magnetospheric particle acceleration for several decades, it was not until the observation and interpretation of upward accelerated ion beams and conical distributions, coherent ion cyclotron wave emissions, electrostatic shocks, and double layers, that the fundamental plasma physics of the aurora began to unfold. Here, again, Mary Hudson's ability to relate observations to theory played a key role in developing this understanding. She, and her research group, performed analytical calculations where needed and established a whole new effort in computer simulation in order to compare observed electric field structures with plasma theory. As a result of this work, a considerable body of knowledge was obtained on the fundamental mechanisms of auroral particle acceleration and the microphysics of large-scale plasma interactions.

While achieving this outstanding research record, Mary Hudson has also taken time to teach both at Berkeley and at a local women's college, and to direct the thesis research of several outstanding students. Thus, she has served as a role model for both young women and young men embarking on scientific careers.

Her many colleagues and friends congratulate Mary Hudson on receiving this award and wish her well in her future research career.

Michael C. Kelley
Forrest S. Mozer
George K. Parks

Acceptance

Thank you Mr. President, Mike, and AGU members. It is an honor to receive this citation from a past Macelwane award recipient. I would also like to thank Forrest Mozer, who labored over the *choice* of words for the citation, George Parks for initiating the Macelwane award effort, and Charlie Kennel for his contribution to the citation. All of these people have contributed to my career, about which I will have more to say.

I would first like to thank my family. My father asked me when I was 7 or 8 years old why I was copying the periodic table of elements onto a shopping bag. I told him "I was doing physics," and he replied, "That's not physics, that's chemistry." I thank my family for such insight and the freedom to explore and discover, even when it meant putting up with an amateur astronomer's hours.

Skipping ahead over my undergraduate days at UCLA, my first real job in the scientific community was with the Space Physics Laboratory at the Aerospace Corporation. After a brief attempt to make an experimentalist out of me, I was given the opportunity by George Paulikas and colleagues to work pretty independently, attend scientific meetings, and generally getting a feeling for research in our field. The encouragement I received and interests I developed while at Aerospace prompted me to seek out Charlie Kennel when I returned to UCLA for graduate school.

Charlie was a great person to work for. He devoted a lot of time to my research problem, and I greatly appreciate the guidance and encouragement he gave me. I was working on equatorial spread *F* at the time, and Charlie suggested that I look at some data, so I contacted Ben Balsley of the National Oceanic and Atmospheric Administration (NOAA) and Mike Kelley at Berkeley, who were involved in a radar and rocket campaign scheduled for summer, 1973. I convinced Charlie that I really ought to go on this experimental junket which was an integral part of my thesis. What I hadn't learned about during my time at Aerospace, because it was a period with few launches, was experimental delays. I planned an elaborate route to Natal, Brazil, for the rocket launches, and called Berkeley the day before my planned departure to find out how people could reach me there. Forrest informed me that the campaign had been delayed for several months and that Mike Kelley was on vacation in Cozumel. At that point Forrest realized that he was dealing with a real theorist, but he gave me the job at Berkeley anyway. I never did make it to Brazil, but Forrest compensated by sending me to Thompson, Manitoba, the next year to launch balloons. Mike was there, along with George Parks. That was about my last adventure in experimental physics. I have, however, maintained my keen interest in the exciting data that has poured out of the Berkeley group and magnetospheric physics in general over the last 10 years.

I got interested in another kind of experiment in the meantime, that is done on computers. Ned Birdsall was teaching his course in plasma simulations at Berkeley, so Doug Potter enrolled to get a user number and I sat in on the course with him. Since then, my collaboration with the Birdsall group has been a mainstay of my research. I brought in Ilan Roth as a post doc, who had been a student of Cuperman's at Tel Aviv, to work with me full time on the simulations. Ilan has been a wonderful person to work with, and has hung in there through the ups and downs of funding and threats of imminent departure.

I started recruiting another Kennel graduate student, Bill Lotko, about 4 years ago. By the time Bill arrived, he had already written a proposal to the National Science Foundation (NSF) to fund his research at Berkeley, and it's been pretty hard to tell him what to do ever since. I thank Bill for his significant contribution to my research efforts and for putting up with my high entropy state.

I thank the rest of the research staff at Berkeley, Kinsey Anderson, and Forrest, who have done a lot more than send me on balloon campaigns to further my career, and the past and present graduate students. I particularly want to thank my own graduate students, Bob Lysak, Earl Witt, and Rachelle Bergmann, and remind you of Chris Russell's encouragement upon receiving the Macelwane award some years ago, that there is still time to accomplish something significant enough to get you to Cincinnati, or wherever the award *is* presented in the future.

Mary K. Hudson

Raymond Jeanloz

Citation

Raymond Jeanloz has made several fundamental contributions to our understanding of the origin and evolution of the solid earth. His research features a broad and innovative attack upon experimental and theoretical geophysics which combines basic principles from physics, chemistry, and geology. His short career has already included contributions to reduction and interpretation of shock wave data, chemical and thermodynamic models of mineral structures, convection and thermal state of the mantle, phase transitions and petrology of the mantle, and high-pressure high-temperature experiments with diamond anvil cells.

His undergraduate education at Amherst College was in geology, and his graduate education at the California Institute of Technology (Caltech) combined geology and geophysics. Tom Ahrens introduced him to high-pressure experimentation and supervised his study of shock effects in lunar materials. This quickly led to a series of studies on anorthosite, anorthite, iron, and olivine. He learned the art of diamond cells at the Geophysical Laboratory of the Carnegie Institution. The brief but intense collaboration combined shock-wave and diamond-anvil experiments to provide one of the first checks of the new ultrahigh pressure calibration scale. About the same time he was also collaborating with Frank Richter in a provocative study of convection in the lower mantle. The construction of his own diamond anvil apparatus led to a series of papers on the effect of crystal structure on mineral properties. His familiarity with experimental data and far ranging interests led to a couple of important review papers on mineral physics, phase transitions, and general petrology of the mantle.

This impressive list of accomplishments in such a young career is a tribute to his capacities for imaginative thinking and tireless work. He has recently established an excellent mineral physics laboratory at the University of California, Berkeley, which allows him and his students to carry out quantitative petrological experiments at ultra high pressures and temperatures by way of the diamond cell and laser heating. Also, his group is combining lattice dynamical theory and vibrational spectroscopy to study the thermodynamic properties of minerals at a fundamental level.

As indicated by those who have been most successful in the past, a broad approach drawing upon several disciplines provides the most promising path to an improved understanding of properties and processes within the earth. Raymond Jeanloz has already made important progress along that path, and, with his versatility, imagination, energy, and youth, we look forward with great excitement to his continued growth as a scientist.

Lane Johnson

Acceptance

Thank you for the kind citation. I am deeply grateful to the Union for granting me this award, and I particularly want to note how pleasing it is to receive early in one's career such recognition from colleagues and friends. By the same token, I am delighted to accept the Macelwane Award as a reflection on my own teachers and associates. From Tom Ahrens, George Rossman, and the other faculty at Caltech, to Frank Richter at Chicago, John Christie at UCLA, and many others, I have been fortunate to be drawn into exciting, high-quality science. Also, I owe special debts of gratitude to Dave Mao, Peter Bell, and their co-workers in Washington, to Sue Kieffer in Flagstaff and, indeed, to my present students and colleagues. Much of what I do now in my research stems directly from collaborations with these individuals.

In this regard, I feel especially lucky because these are exciting times in mineral physics and experimental geophysics. It is just now becoming possible to carry out sophisticated, quantitative studies on minerals at the extreme conditions of temperature and pressure existing near the earth's center. The resulting data provide fundamental insights into the ways in which the planetary interior evolves. At the same time, we are beginning to achieve a basic understanding of the complex solids and fluids that make up this planet. In this area, particularly, I believe that geophysics has much to contribute to the neighboring disciplines of physics, chemistry, and materials science, as well as to the earth sciences. For example, the high-pressure diamond-anvil cell, which has been developed primarily for geophysical and geochemical research, is now having a major impact in condensed matter research in chemistry and physics. As a result, I believe that there is a very healthy and exciting increase in the communication and collaboration between these fields.

I think that this increasing breadth in the area of mineral physics is in no small part due to the unselfish and highly cooperative attitude of our community. I bring this up because the support, the education, and the inspiration provided by this community has been of primary importance to my own development, and I want to take this opportunity to thank my colleagues.

Raymond Jeanloz

John H. Woodhouse

Citation

John H. Woodhouse was born in England on April 15, 1949. His academic degrees are from the University of Bristol, where he received the B.Sc. degree in 1970, and from the University of Cambridge, where he received the Ph.D. degree in 1975. The world renowned Department of Applied Mathematics and Theoretical Physical was his professional home and John A. Hudson his mentor during his postgraduate years.

Most of Woodhouse's early work was concerned with wave propagation, although his third publication on Rayleigh's principle revealed his insight and fundamental clarity of thought about low frequency seismology. This work led to his collaboration with F. A. Dahlen and his important publication in 1980 on the coupling and attenuation of nearly resonant multiplets in the earth's free oscillation spectrum. In that paper one finds the basis for much of today's research on the subject.

After a Fellowship at King's College, Cambridge, and a postdoctoral year at the University of California, San Diego, Woodhouse joined the faculty at Harvard, where he is now professor of geophysics. There he began a fruitful collaboration with Adam Dziewonski that has led to the first three-dimensional maps of the structure of the earth's mantle. Like the efforts of the early cartographers of the 14th century, the recently produced maps of the mantle are certainly to be approximations to the truth, containing distortions and misperceptions of various kinds. Yet, they are important first steps on the road to the discovery of the three-dimensional structure of the earth, and Woodhouse's contributions to their construction are profound. Perhaps, as Prince Henry the Navigator improved on the results of the 14th-century cartographers, John Henry Woodhouse will continue to improve on today's results.

There are many other facets to the professional career of John Woodhouse, such as his work on earthquake source mechanisms, asymptotic results for propagator matrices, methods for performing seismic calculations, etc. However, it is primarily his outstanding research on the determination of three-dimensional structure that is the basis for this award.

Many people of stature derive prestige from the institutions of higher learning with which they are associated. In the case of John Woodhouse he is a Cambridge Ph.D. and a *Harvard professor*. There are a few people who, by virtue of their own accomplishments, confer status on their institutions. John Woodhouse is one of these few. Both the University of Cambridge and Harvard University stand higher in geophysics because of the accomplishments and reputation of John H. Woodhouse.

J. Freeman Gilbert

Acceptance

Thank you Mr. President and thank you Freeman for your very kind remarks. To have to respond on such an occasion places one in a position which is the reverse of what is usual at a scientific meeting. Often one may strongly wish to refute a position taken by a colleague, but not have adequate ammunition. On this occasion I have no wish, whatever, to disagree with the speaker, but I am only too aware of the contrary information which could be brought to bear on the matter.

To accept this award is a singular honor and pleasure, which derives from the respect in which one holds the previous recipients and one's colleagues who have conferred the award.

On a personal level it is an occasion to look back and review the path one has traveled. I am reminded of a time when, it seemed to me, my career in geophysics was at an end. Hal Thirlaway was attending a meeting in Cambridge, England, and I was to arrange to have his slides transmitted to the projectionist. Taking hold of the tray, my hand slipped, and the carefully arranged selection of glass mounted slides was scattered on the stone floor. Many were broken, and their order was completely disrupted. This was also an occasion to admire the professionalism of an esteemed colleague, since he went on to give a most lucid presentation, seemingly unperturbed by the erratic sequence and evident damage which his slides had sustained. Well, my career in geophysics did not end at that point, though I did find it necessary to emigrate.

I would like, on this occasion, to express gratitude to friends and colleagues. I wish to thank John Hudson, my advisor at Cambridge, for his advise and support during my graduate student career. At that time I was entirely theoretical, and the pleasure I took in my work was like that of doing a crossword puzzle. From Cambridge I went first to Scripps and then to Harvard, and I would like to thank Freeman Gilbert and Tom Jordan for the important influence they had on my work. Particularly, I express my thanks to Adam Dziewonski, from whom I have learned vastly more than I knew when I first came to Harvard, particularly with regard to the understanding of seismic data. If the pleasure I took in theoretical seismology was like that of doing a crossword puzzle, it became infinitely more rewarding when Adam equipped me with some of the clues.

This award comes at a time when one has just been in the profession long enough to have some perspective and to see the way in which the science evolves. I feel that I have been particularly fortunate to have witnessed the developments since 1975. In the last 10 years we have seen the development of techniques for the calculation of theoretical seismograms, the advent of global, digital instrumentation, and the growing availability of ever more powerful computers. These developments have set the scene for major new advances in seismology, and, so, to the younger seismologists in the audience I would say that you, as I, could not have chosen a better time to enter the field.

With the new initiatives in global seismic instrumentation and in lithospheric studies, our science is about to enter one of its more exhilarating periods, in which many longstanding questions should be answered. In the words of an esteemed colleague—who may or may not wish to identify himself—"the earth is up for grabs."

John H. Woodhouse

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Regular Members

Spyridon Coubis (GP), Francois Fauchet (G), Catherine Gilroy (H), Abram R. Jacobson (SA), J. Edward Joyce (O), Benny L. Klock (G), Roger McCoy (GP), Richard G. Miller (O), Chee Keung Ng (SS), Shangyou Nie (T).

Richard Pearson (A), Mulia Purba (O), Christos Repapis (A), Ronald Schalla (H), Dorothy G. Swift (O), Charles H. Tang (H), Martha L. Zirbel (H).

Student Status

Mark A. Baker (O), Steven Balsley (V), Harold E. Brooks (A), Donald H. Burn (H), Dennis A. Clark (T), Cheryl Contant (H), Robert E. Crippen (T), Ken Hon (V), Ingemar P. E. Kinnmark (H), B. Makinde-Odusola (H), Martin A. McGilvary (T), Biswajit Mukhopadhyay (V).

Clyde E. Rhodes (T), Stephen M. Richard (T), M. Lee Ringland (T), Kenneth R. Sperber (A), Hideki Takamiya (V), Elizabeth A. Velz (T), Richard Volkert (V), Jim Warner (T).

Meetings

Announcements

Risk Analysis

September 18–20, 1984 Risk Analysis in Environmental Health—With Emphasis on Carcinogenesis, Cambridge, Mass. Sponsor: Harvard Univ. School of Public Health. (Office of Continuing Education, Dept. A, Harvard Univ. School of Public Health, 677 Huntington Ave., Boston, MA 02115; tel.: 617-732-1171.)

Among the topics to be discussed are the problem of risk analysis in the context of calculating risks when data are uncertain; the methodologies for risk evaluation; and the interplay of risk evaluation and risk assessment. Introductory sessions will be devoted to an overview of techniques for assessing environmental cancer risks. Subsequent sessions will focus on health risks associated with chemical contaminants in the ambient environment and with airborne radon in the environment and the home. Uses and limitations of epidemiology and data from animal studies will be emphasized.

Petroleum and Natural Gas

September 24–25, 1984 Petroleum and Natural Gas Markets Conference, Calgary, Alberta. Sponsors: Canadian Energy Research Institute, Calgary Chamber of Commerce. (Shane Streifel, Conference Director, Canadian Energy Research Institute, 3512 33rd St. NW, Calgary, Alberta, T2L 2A6, Canada; tel.: 403-282-1231.)

Leading authorities from around the world have been invited to provide insights on recent and anticipated developments in the world oil market and North American natural gas markets. Topics to be discussed include the outlook for the world oil market; political uncertainty in the Middle East; the economics of refining and upgrading heavy crudes; prospects for a natural gas futures market; U.S. heavy crude oil outlook; changing corporate strategies; and heavy crude oil markets.

Geopotential Research Mission Conference

October 29–31, 1984 Conference on Geopotential Research Mission (GRM) Science, College Park, Md. Sponsor: NASA. (L. Walter, Code EE-8, NASA Headquarters, Washington, DC 20546; tel.: 202-453-1675.)

The conference will feature invited and contributed papers on the interpretation and application of variations in the earth's gravity and magnetic fields on the scales that will be measured by GRM. The subjects of the conference are Dynamics and Structure of the Sub-Ocean Lithosphere and the Continents, Mantle Convection, The Dynamics of the Core, and Ocean Circulation.

Lunar Bases and Space Activities

October 29–31, 1984 Symposium on Lunar Bases and Space Activities of the 21st Century, Washington, D.C. Sponsor: National Aeronautics and Space Administration. (Michael Duke, NASA Johnson Space Center, Houston, TX 77058; tel.: 713-483-4464.)

The deadline for contributed abstracts is September 3, 1984.

The purpose of the symposium is to explore the rationale, uses, technical requirements, feasibility, and implications of a lunar research base or bases as a long-term objective of the space program. Topics of contributed and invited papers will include scientific experiments at a lunar base; economic utilization of lunar resources; technological feasibility of a permanent base; societal implications and politics of a permanent base; international cooperation in lunar activities; program elements and options; phased development of a lunar base; lunar power, transportation, and habitation infrastructure; and necessary technological and scientific development.

Water and Coal

February 26–28, 1985 Second Hydrology Symposium on Surface Coal Mining in the Northern Great Plains, Gillette, Wyo. Sponsor: Gillette Area Groundwater Monitoring Organization. (Ron Landers, Carter Mining Company, P.O. Box 3007, Gillette, WY 82716; tel.: 307-682-8881.)

The deadline for abstracts is September 1, 1984.

The purposes of the conference are to provide a forum for the exchange of information on surface and groundwater hydrology at surface coal mines in the Northern Great Plains and to present ideas and concepts relating to studies of premining hydrological conditions, relating to predictions of mining-related hydrologic impacts, relating to designs of hydrologic control facilities, and relating to successful reclamation of disturbed hydrologic systems.

Suggested topics of interest include surface and groundwater monitoring; alluvial valley floors; groundwater modeling; regulations and guidelines; backfill hydrologic characteristics; backfill water quality; stream channel reconstruction; stable postmining topography design; and prediction of site specific and cumulative hydrologic impacts.

Integral Methods

March 18–21, 1985 International Conference on Integral Methods in Science and Engineering, Arlington, Tex. Sponsor: University of Texas at Arlington. (Fred R. Payne, A.E. Dept., UT-Arlington, 76019; tel.: 817-273-2074.)

The deadline for abstracts, (which should be approximately 200 words) is September 15, 1984.

Among the pertinent topics to be covered are analysis; applied probability and statistics; artificial intelligence; catastrophe theory; CFD/computational aerodynamics: theory and numerics; control and feedback theory; discrete mathematics; FEM: analysis and practice; integral and integro-differential equations: theoretic and applied; and microprocessor capabilities and forecasts.

The objectives of the conference are to provide a forum for discussing integral methods of all types and to bring together workers who use integral methods, including those who work in geophysics, astrophysics, biophysics, chemistry, engineering, applied mathematics and mechanics, field theory, continuum and discrete mechanics, organic and inorganic processes, probability and statistics, bioengineering, classical engineering, quantum physics, and transport phenomena for pollutants and contaminants.

Hydrology Days '85 Call For Papers

April 16–18, 1985 AGU Fifth Annual Front Range Branch Hydrology Days, Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colorado State University, Fort Collins, CO 80523; tel.: 303-491-5448 or 8549.)

The deadline for acceptance of abstracts (or telephone calls) is December 31, 1984, for professional hydrologists, and February 15, 1985, for students.

The AGU Front Range Branch is planning three Hydrology Days at Colorado State University, April 16–18, 1985. The objective of the meeting is to provide a forum for hydrologists and hydrology students to meet, get acquainted, and hear each other's problems, analyses, and solutions. Several special sessions will be held with keynote addresses by recognized hydrologists.

During the 3 days there will be presentations of volunteered papers (mostly), invited papers (a few), and papers by students (on the first day). The time allocated for presentation will depend on the response to this call for papers. Tentatively, the time allotted per paper will be about 25 minutes, including discussion. Standard visual aids (regular and overhead projectors) will be provided.

Hydrologists and hydrology students interested in presenting a paper should send a one-page sheet (original plus one copy) with their name, affiliation, complete mailing address, telephone number, title of paper; a brief, double-spaced typed abstract, roughly one-half page long; and an abstract fee of $10.00 (no fee for students) to the above address.

Papers missing the abstract deadline may be scheduled for presentation but may not appear on the program to be mailed out during the last week of February and advertised in *Eos* shortly thereafter. Proceedings of the conference will be published and available at the meeting. Preference on the program will be given to authors who intend to provide a written version (guidelines and special paper will be provided on request) of their oral presentation. The deadline for submission of the written version is March 1, 1985.

There will be no registration fee for students. There will be a small registration fee (between $20 and $30) for others to cover room rental fees, coffee breaks, programs, copies of abstracts, and other minor expenses. Final registration details will be available when the program is advertised in February in *Eos*.

The AGU Front Range Branch will present awards and prizes to the best student papers in two categories: M.S. and Ph.D. candidates. At a luncheon, the third award for outstanding contribution to hydrology will be presented. Please send nomination suggestions for this award to Hydrology Days Award Committee, c/o H. J. Morel-Seytoux at the above address.

Meeting Report

Archean Geochemistry

A cross section of the Archean crust provided the focus of the 1983 Archean Geochemistry and Early Crustal Genesis Workshop that convened in Ottawa on August 10, 1983. Forty-six geoscientists registered: 24

Meetings (*cont. on p. 454*)

Meetings (cont. from p. 453)

from the United States, 16 from Canada, three from Australia, and one each from West Germany, the Peoples' Republic of China, and Zimbabwe. The workshop was sponsored jointly by the Geological Survey of Canada (GSC), the International Geological Correlation Project (IGCP), the Lunar and Planetary Institute (LPI), the National Aeronautics and Space Administration (NASA), and the Ontario Geological Survey (OGS).

The workshop was divided into an opening day of 16 formal papers, followed by a 6-day field trip. Expanded abstracts of the 16 presented papers and four more that were not presented were included with the 70-page field trip guide given to each registrant.

Proceedings got underway in Alice Wilson Hall at the GSC, where the registrants and a roughly equal number of onlookers from the Ottawa geological community were welcomed by J. G. Fyles (Chief Geologist, GSC). The formal papers dealt with the various facets of the origin and evolution of Archean crust. Jim Wilson (University of Zimbabwe) led off the morning session by providing evidence for correlations between Zimbabwean greenstone belts. Kent Condie and Phil Allen (New Mexico Institute of Mining and Technology) discussed and illustrated with beautiful field photos from peninsular India the transition of an Archean granite-greenstone terrane into charnockite. Dave Fountain (University of Wyoming) followed with a discussion of crustal cross sections, using the Ivrea zone of the Italian Alps and the Archean subprovinces of northern Manitoba as his examples. Werner Weber (Manitoba Geological Services Branch) reported on the relatively felsic Pikwitonei granulite domain of northern Manitoba, interpreted as a lower crustal level exposed at the northwestern end of the Superior province. Lew Ashwal, P. Morgan, and W. W. Leslie (LPI) spoke on a mystifying problem of granulite-facies metamorphism: how to carry supracrustal rocks to great depths, metamorphose them to high temperatures and pressures, and then reexpose them at the surface, where they are still underlain by normal thicknesses of continental crust. Roberta Rudnick, now at the Australian National University (ANU), Lew Ashwal, and Darrell Henry (LPI) showed through fluid inclusions studies that CO_2 was virtually the exclusive fluid phase during granulite-facies metamorphism of rocks in the Kapuskasing structure. Gil Hanson (State University of New York at Stony Brook), developed the use of olivine and plagioclase saturation surfaces to place limits on the compositions of cumulate phases and intercumulus melts as well as to define processes of melting in the mantle.

Ross Taylor (ANU) started the afternoon session with an outline of the development of continental crust based chiefly on systematic changes in the distribution of REE's in fine-grained clastic rocks through time. Bob Dymek (Harvard University), J. L. Boak (Arco), and L. P. Gromet (Brown University), followed by Ullrich Rast (Max Planck Institute, West Germany) presented papers on the chemical evolution of the 3.8 Ga Isua supracrustal rocks in western Greenland. George McGill (University of Massachusetts) then spoke on the tectonic evolution of Venus, pointing to possible analogues with earth's Archean greenstone belts. George Tilton's (University of California, Santa Barbara) treatment of crust-mantle differentiation, based on the evidence of Pb isotopes, suggested that depleted mantle originated about 2.7–3.0 Ga ago in several areas of the Superior Province. On the other hand, Sm-Nd isotopic systematics of the Ancient Gneiss Complex of South Africa, and of rocks in the Rainy Lake area, Ontario, as discussed in two papers, respectively, by R. W. Carlson (Carnegie Institution), D. R. Hunter (University of Natal), and F. Barker (USGS), and S. B. Shirey and Gil Hanson (State University of New York at Stony Brook), indicate that zones of depleted mantle existed at 2.7 Ga and probably before 3.5 Ga. Listeners were then vicariously brought back to India by J. D. Macdougall (Scripps, La Jolla, Calif.) and three coauthors who discussed a possibly depleted mantle source under Archean crust in Rajasthan. The day's last formal paper, by Ken Collerson (ANU), reported 3.9 Ga zircons from the Uivak gneisses in northern Labrador, the oldest ages yet reported from the North American-Greenland landmass. At the prodding of colleagues, Collerson closed the afternoon with an informal report on work just carried out on the ANU ion microprobe by a number of graduate students under the supervision of W. Compston. This work, now in press, determined the existence of zircons at Mt. Narryer, western Australia, between 4.1 and 4.2 Ga old. The "beginning" gets pushed back farther and farther.

The field trip focused on the Kapuskasing structure, a 500-km long curvilinear feature that slices northeastward through the Archean Superior province from the eastern shore of Lake Superior to the Moose River basin near James Bay. The structure was first recognized by *Garland* [1950], who crossed it on two regional gravity traverses in northern Ontario. He called attention to a belt of positive Bouguer anomalies (the "Kapuskasing-Fraserdale high"), which he attributed to a northeastward-trending band of "thinned granitic layer." Subsequent gravity mapping with appreciably greater station density by *Innes*, [1960] succeeded in outlining most of the structure. Innes suggested that the Kapuskasing-Fraserdale gravity high reflected a major tensional feature of the crust, perhaps not unlike the East African rift zone.

Whereas these early interpretations on the origin of the Kapuskasing structure were based on a tensional tectonic regime, current views lean the opposite way, namely that the structure is a slice of Archean lower continental crust, exposed at the surface by erosion following an episode of obduction. By this interpretation, the Kapuskasing structure exposes a crustal cross section 20–25 km thick, with progressively deeper levels laid bare eastward from the Michipicoten greenstone belt of the Wawa area, through the Wawa domal gneiss terrane, to the far edge of the Kapuskasing structure at the Ivanhoe Lake cataclastic zone, interpreted as the westward-dipping detachment surface at the base of the obducted crust [*Percival and Card*, 1983]. The low-grade Abitibi greenstone belt east of the Kapuskasing structure would therefore be correlative with the Michipicoten belt. The progressive increase of metamorphic grade eastward to reach the granulite facies at the Ivanhoe Lake cataclastic zone (quantitatively traced by various mineralogic geobarometers and geothermometers [*Percival*, 1983]), the attitude of basaltic dikes, Bouguer gravity anomalies, and the lithologic similarity of the Michipicoten and Abitibi greenstone belts are in keeping with the proposed interpretation [*Percival and Card*, 1983].

The field trip began on Thursday with an 800-km, all-day ride by chartered bus from Ottawa to Sault Sainte Marie. The day's geology consisted of brief descriptions of many roadside outcrops as they whizzed by at 100 km/hr. The first working day of the field trip was Friday when, in the Wawa area, the lowest-grade part of the Michipicoten greenstone belt was examined in road cuts as well as in active and abandoned iron mines. These outcrops provided a baseline for the comparison of relatively undisturbed characteristics of supracrustal rocks with their progressively more metamorphosed equivalents (or potential equivalents) to be seen during the next 2 days. Metasediments, including conglomerates, a variety of felsic metavolcanic rocks with well-preserved primary textures, mafic metavolcanic rocks which are locally pillowed, oxide and carbonate iron formation with intraformational breccias, and metasomatic(?) chloritoid rocks evoked lively discussions and the expenditure of vast quantities of film. At some outcrops, the clicking of shutters masked the blows of hammers.

Day 2 brought the field trip eastward into the amphibolite-grade Wawa domal gneiss terrane in the vicinity of Chapleau, a railroad town deep in the bush. Here, participants viewed tonalite gneisses with enclaves of amphibolite interpreted to be partly digested dismembered fragments of Michipicoten greenstone; various granitic rocks disposed in a series of domes; and, at the day's end, "granulite" gneiss in the Robson Lake dome which shares the structural attributes of the Wawa domal gneiss terrane and the lithological characteristics of the Kapuskasing structure. Hotly discussed on day 2 were such topics as the significance of the fine-scale and persistent layering in the felsic and intermediate gneisses, the nature of the protolith for the gneisses, and the mechanism by which dense mafic gneisses can be incorporated in the upwelled cores of the domes.

On day 3, participants were guided easterly through the Kapuskasing structure, past the Ivanhoe lake cataclastic zone, and into the Abitibi greenstone belt beyond, ending up at Timmins. Gneisses in the Kapuskasing structure are relatively more mafic than those in the Wawa domal gneiss terrane, and many are characterized by interlayers of gneiss with garnet + clinopyroxene + plagioclase and gneiss with hornblende + garnet. Whether these mineralogical contrasts are the result of retrograde metamorphism, P_{H_2O} gradients during prograde metamorphism, compositional differences in the protoliths or mobilization of partial melts during granulite metamorphism provided a subject of lively debate among the petrologists. Another provocative subject was, What is the role of orthopyroxene in defining granulite? Two stops in the Shawmere anorthosite complex were particularly impressive. The complex makes up an irregular, lens-shaped, regionally concordant pluton 50 by 15 km, with a satellite body to the south. Coarse-grained anorthosite, gabbroic anorthosite, and gabbro, in part deformed cataclastically, elsewhere with corona textures, are the chief rocks. Gray intermediate to calcic plagioclase, garnet, black hornblende, and orthopyroxene are conspicuous in hand specimens. The Ivanhoe Lake cataclastic zone, not well exposed, was studied in a single outcrop, where mafic gneiss is sliced by veins of black recrystallized aphanitic mylonite. The Abitibi greenstone belt immediately east of the cataclastic zone is made up of fine-grained, layered, east-striking, little-disturbed basaltic metavolcanic rocks. The contrast is remarkable between these weakly metamorphosed rocks and the coarse-grained, high-grade, northeast-striking, banded gneisses in the Kapuskasing structure across the cataclastic zone only a few hundred meters to the west. Consistently east-dipping Archean basaltic dikes in the Kapuskasing structure were cited as additional evidence of upward ramping on an inferred west-dipping basal fault.

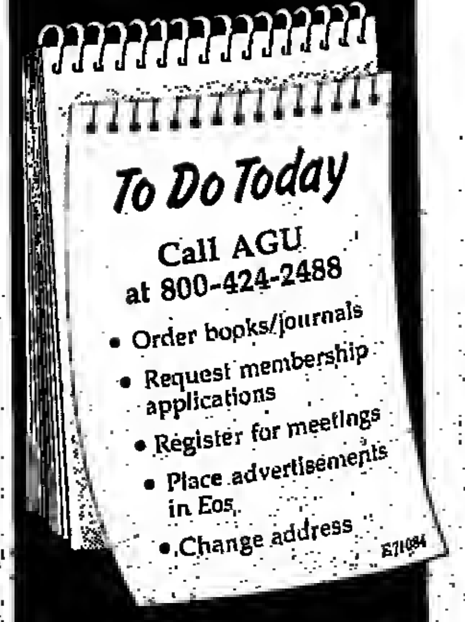
Day 4 was spent in the Abitibi greenstone belt in the vicinity of Timmins, where numerous metavolcanic and metasedimentary rocks of greenschist and subgreenschist grade were examined. At the first stop, top and bottom criteria were discussed avidly on a bleach-cleaned outcrop that exposes an angular unconformity between greywacke and overlying conglomerate. Other stops during the day included altered and pillowed(?) komatiites, complex successions of Mg-rich and Fe-rich metatholeiites, excellent displays of variolites, and a complex series of felsic tuffs and breccias. Day 4 ended earlier than previous days in the field to permit a late-afternoon meeting at the motel to discuss plans for future Early Crustal Genesis meetings and to provide written summaries of work underway or planned on the Kapuskasing structure. The results of this meeting are included in later paragraphs. Following a banquet dinner, Larry Jensen (OGS) closed the day's formalities with a talk that illustrated his views on the origin of Archean greenstone belts based on more than 10 years of his detailed studies of the Abitibi belt.

About half of the participants left the trip at Timmins by air early on day 5. The enthusiasts that remained carried on to see komatiite and other metavolcanic and metasedimentary rocks of the Abitibi greenstone belt at Kirkland Lake. "No-hammer outcrops" included komatiite with spinifex texture and metaconglomerate with komatiite clasts.

There was an overwhelming concensus that the field trip focused successfully on the problem under scrutiny. Through a series of well-chosen exposures, mostly of excellent quality, the pieces of the Kapuskasing puzzle were viewed in the logical order. Surprisingly, however, was the limited areal extent of undisputed granulites. In part, these rocks are spatially related to the Shawmere anorthosite complex, a structurally and petrologically snarled unit with evidence of having been transported upward relative to enclosing rocks. Certainly, the presence of granulite-facies rocks in the Kapuskasing structure requires explanation, but their quantitative importance pales before the thousands of square kilometers of granulite exposed elsewhere in the Superior province, the Churchill province, and the Grenville province. Although the age of the thrusting thought to be responsible for the Kapuskasing structure is known imprecisely, it is no younger than early late Proterozoic, and it may be Archean [*Percival and Card*, 1983]. The operation of compressional forces on such a vast scale is not in accord with the commonly held view of the dominance of vertical tectonics in early earth history. Upcoming lithoprobe studies in the Kapuskasing structure, particularly seismic experiments, should provide answers to many questions yet unanswered about this fundamental crustal feature of the shield.

From the discussions during the late-afternoon meeting at Timmins there came many suggestions for research in the field trip area, and much of this research is either already underway or planned by the participants, commonly in collaborative efforts that were arranged during the workshop. Many attendees expressed the desire to work collaboratively with others, either within the already proposed efforts or in new efforts. The suggested research for the area can be grouped into three categories, all of which are necessary for a better understanding of the early evolution of planetary crusts: (1) acquisition of basic data, (2) better understanding of processes in the lower crust, and (3) development of models for evolution of the crust-mantle system. The first category includes studies aimed at developing detailed structural and stratigraphic data, complete geophysical characterization on a regional scale, and thorough characterization of the range of rock types (petrography, geophysical properties, and compositions). Such data are required for proper collecting of samples, placing constraints on models, comparison with other areas, and tracing of units through the crustal section. The second category includes studies aimed at better understanding of the role of fluids during metamorphism, the products of partial melting in the crust, the evolution of thermal gradients in the crust, the chemical and isotopic changes that develop in supracrustal rocks when taken to the lower crust, and the tectonic roles of various igneous rocks in the lower crust. The third category includes studies aimed at determinations of the extent of geochemical provinces in the Archean mantle; the chemical and isotopic evolution of the mantle through time; the interaction between mantle-derived melts and the crust; the history of tectonic, igneous, and metamorphic events in the Archean; and evidence for pre-Archean crustal formation.

Among the present and planned research efforts, there are eight in the first category. These range from detailed mapping of the supracrustal rocks in the Wawa belt, through refinement of the Kapuskasing gravity data, to measurement of sonic velocities at high *P* and *T* for a collection of rocks from the Kapuskasing structure. There are 11 research efforts involving 17 of the workshop participants in the second category. These range from fluid inclusion and oxygen isotope studies across the entire structure for determination of fluid interactions, through comparisons of compositions and isotopes between low grade Michipicoten greenstones and high grade Wawa-Kapuskasing gneisses, to the relations between trondhjemitic to granitic partial melts and their assumed residues in Kapuskasing granulites. There are seven studies in the third category, most of which will utilize some combination of Pb, Sr, and Nd isotopes in the various igneous and metamorphic rocks of the cross section to develop models for mantle heterogeneities, mantle evolution, and crustal contamination.



From the open discussion period there were several ideas that seemed to recieve general agreement. Field workshops of this type were considered to be an excellent means of exchanging ideas, developing new approaches, and coordinating research plans. Furthermore, thematic or process-oriented field workshops could serve as the basis for future conferences or special sessions at regular annual meetings of geoscience organizations. Special issues or sections of journals could be devoted to papers that resulted from the workshops and conferences. To coordinate these efforts, an advisory group for the Early Crustal Genesis Program should be established to include representatives of other organizations with similar research interests. This group would develop a long-range schedule of topics, workshops, meetings, etc., to promote coordination and communication and avoid conflicts and excessive overlap. A newsletter containing such information should be distributed to interested persons with some degree of regularity.

Acknowledgments

Parts of this report were taken from another report on this workshop submitted to Geoscience Canada by Tomas Feininger of the Earth Physics Branch, Canadian Ministry of Energy, Mines, and Resources, Ottawa.

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This meeting report was contributed by William C. Phinney, NASA/Johnson Space Center, Houston, TX 77058.

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